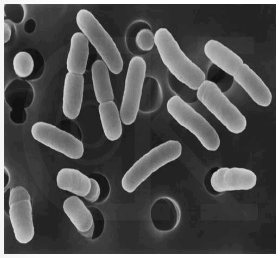
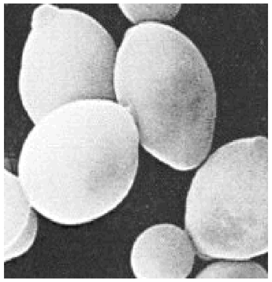
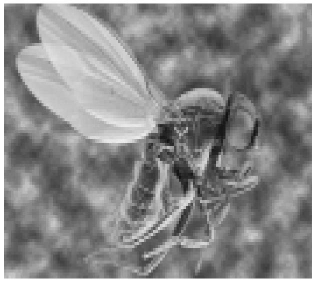


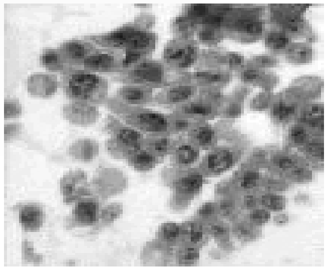
Life Interacts with the Physical World



Terri Lomax
Fundamental Space Biology Division
NASA Headquarters



OBPR
Free Flyer Workshop
NASA Ames Research Center
December 2, 2003



Fundamental Space Biology

Fundamental Space Biology (FSB) is NASA's agency-wide program for the study of fundamental biological processes. The program has four primary goals:

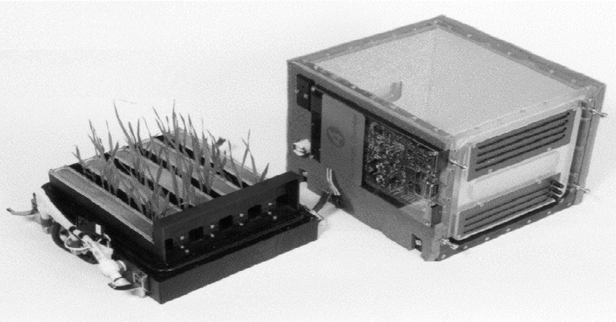
1. Develop the foundation of fundamental biological knowledge required to enable a long-duration human presence in space

2. Use microgravity and the other characteristics of the space environment to enhance our understanding of fundamental biological processes

- **Develop the biological understanding to support other NASA activities related to biology**
  - **e.g. Astrobiology (Space Sciences), Terrestrial Ecology, and Public Health (Earth Sciences)**

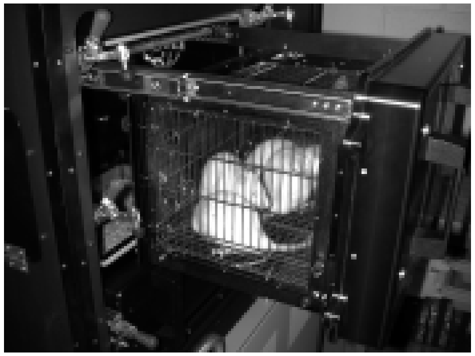
4. Apply this knowledge and technology to improve our nation's commercial competitiveness, education, and quality of life

FSB Program Content



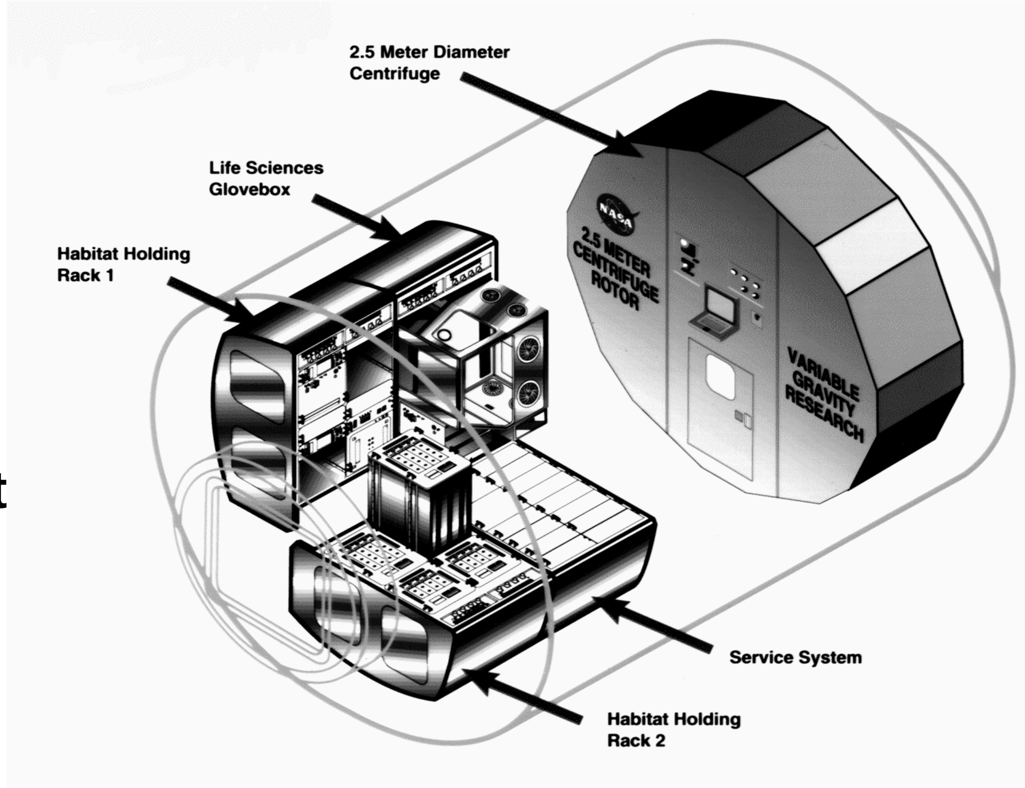
Research &Technology

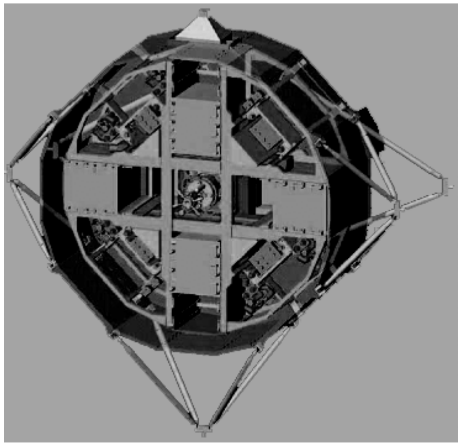
- **Ground research including unique ground facilities e.g., centrifuges, Brookhaven**
- **Flight research - including hardware development**
- **Includes funding for Early ISS Cell & Molecular Science and the FSB portion of the Radiation Health Initiative (together with BR & PSR)**
- **Technology development for *in situ* biology and telemetry**



FSB Program Content

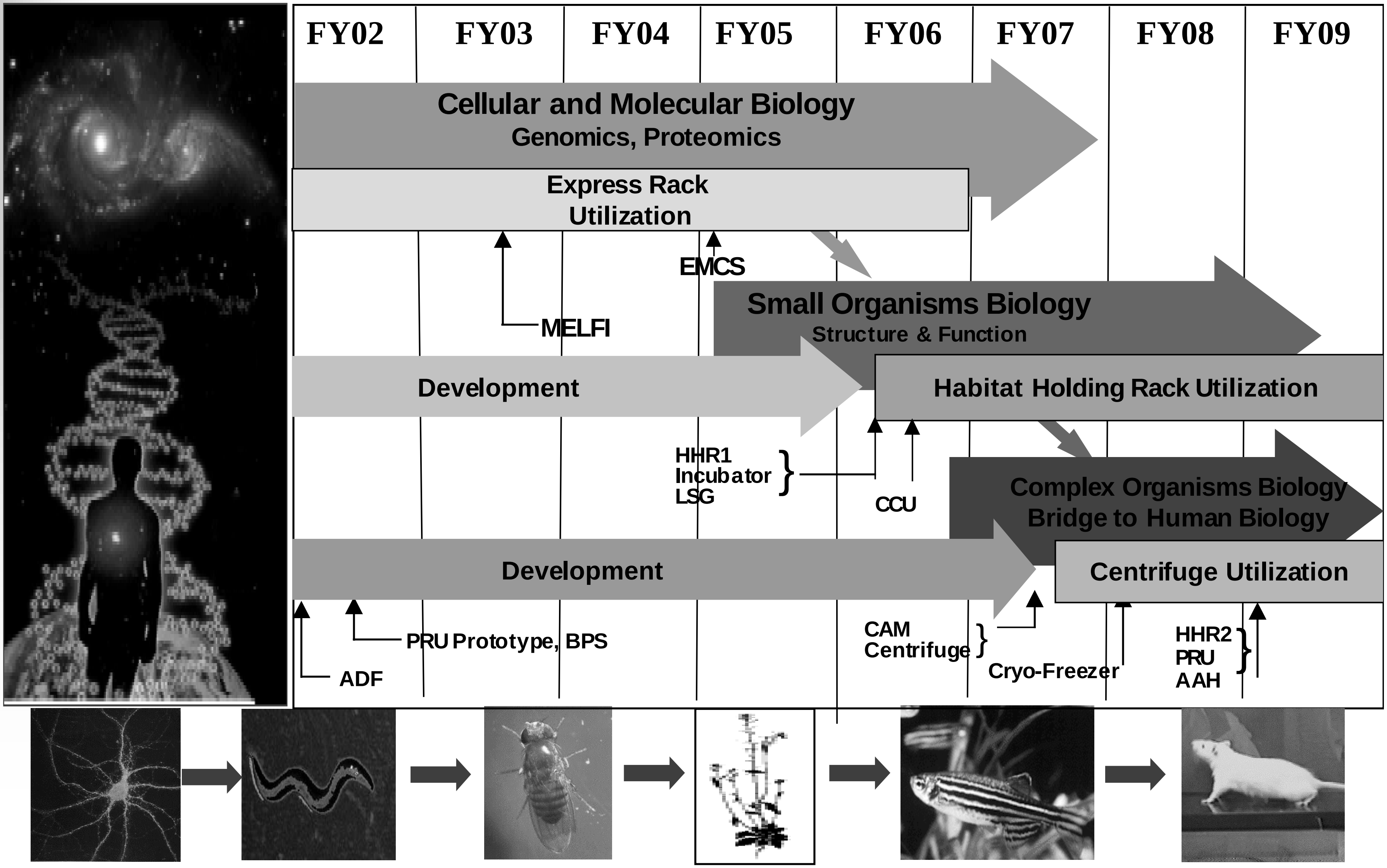
- **Space Station Biological Research Project**
  - **Habitat Holding Racks 1 & 2**
  - **Incubator**
  - **Cell Culture Unit**
  - **Insect Habitat (CSA)**
  - **Aquatic Habitat (JAXA)**
  - **Centrifuge**
  - **Life Sciences Glovebox**
  - **Plant Research Unit**
  - **Advanced Animal Habitat**



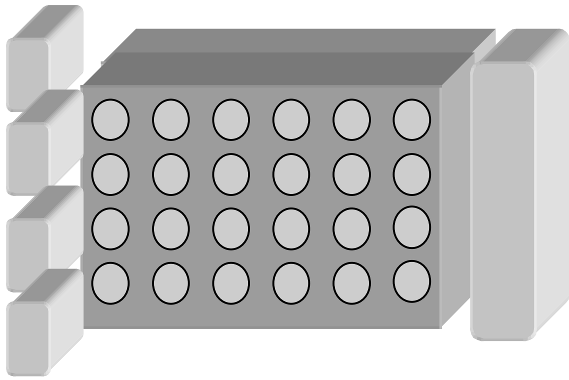


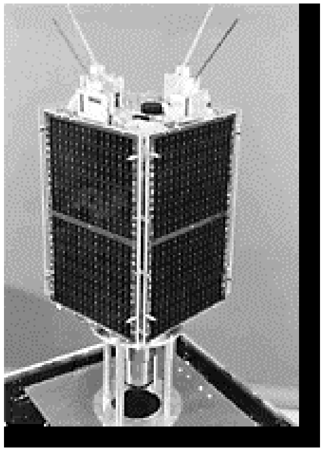
FSB Program Content

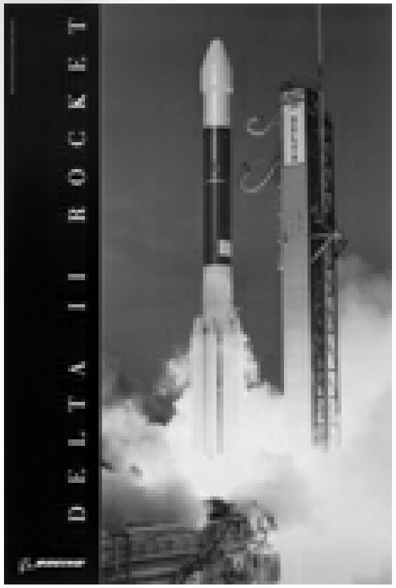
Progression of Fundamental Biology Research on the ISS

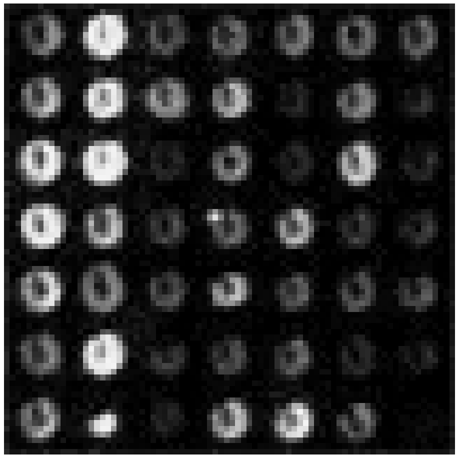


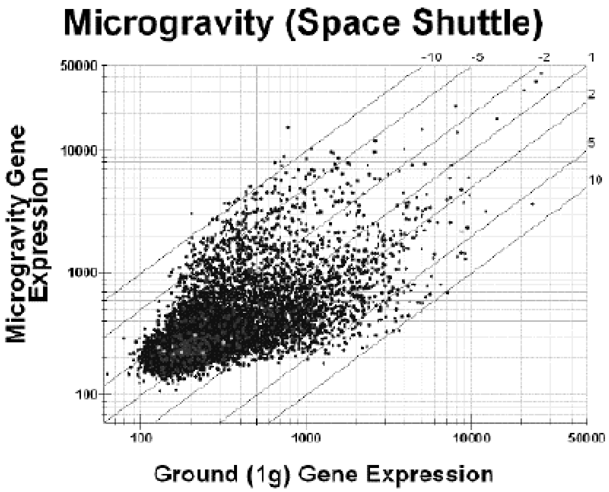
In-situ *Space Genetics Experiments on Nanosatellites (ISGEN) Technology Accelerator Project*





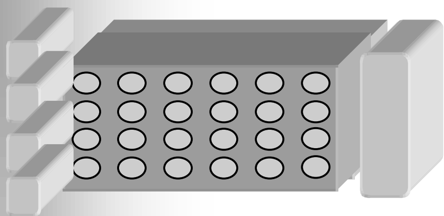




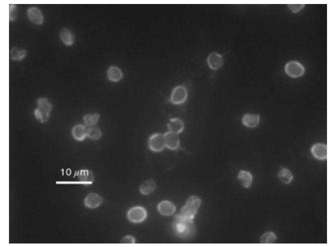


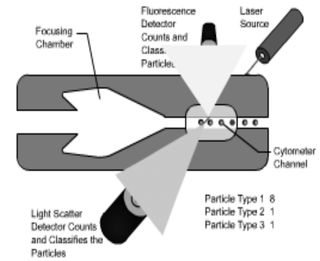
ISGEN Technology Flow

Sample Management | **Imaging** | **Detection and Analysis**

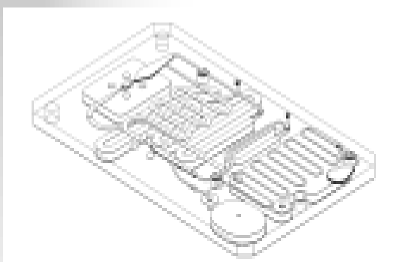


μWellplates

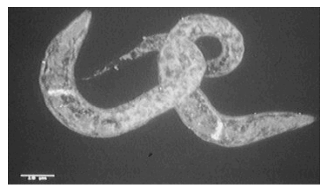




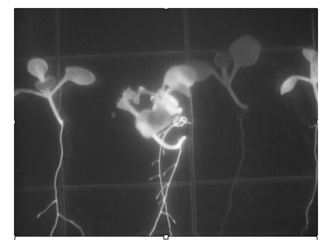
Cytometry



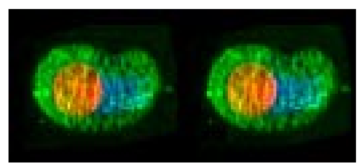
μfluidics



Single-wavelength

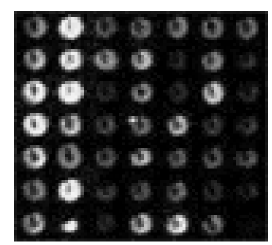


Spatial Imaging



Multi-wavelength

PCR

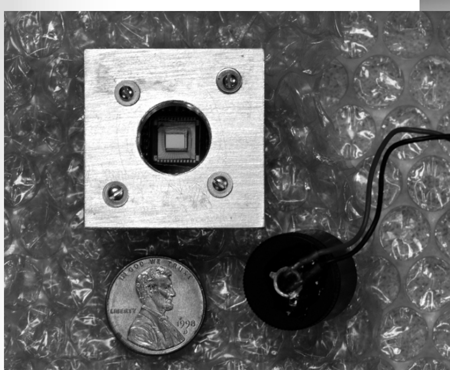


Arrays (DNA, Proteins)

NemaSat (ISGEN Precursor)

- **The NemaSat Project = ISGEN precursor activity using nematodes as model organism**
  - **Balloon test flight has been successfully conducted in collaboration with the Iowa State University Space Sciences balloon test group.**
  - **ISGEN may also take advantage of similar balloon expeditions**

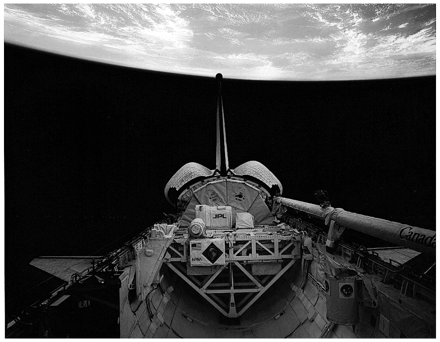
- **NemaSat is lead by the Stanford National Center for Space Biological Technologies (NCSBT)**
  - **NCSBT Scope:**
    - **Design and development of advanced, *in-situ* Space Biological Instruments and concepts**
    - **Demonstration of relevant technologies in ground-based simulation facilities**
    - **Balloon tests and demonstration flight exercises**
    - **Development and flight of biological payloads for small-satellite (Cubesat/NanoSat) applications.**



Balloon Flight
Iowa State Univ.
July 2003

Expanding OBPR's research capabilities

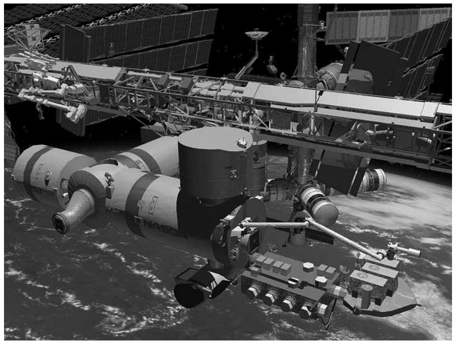
Space Shuttle
1985 - 2015



Key Capabilities

- **Short Duration micro-gravity environment**
- **Crew tended**
- **Circular orbit**
- **28 – 57 degree inclination**
- **300 km altitude**
- **Return Capability**

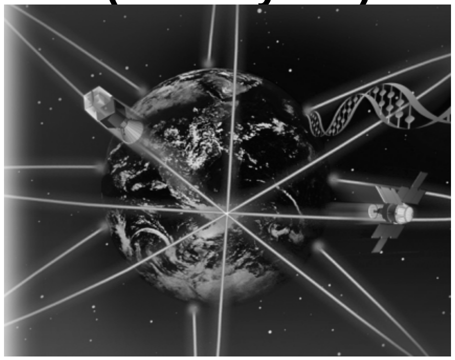
Space Station
2003 - 2015



Expanded Capabilities

- **Long Duration micro-gravity environment**
- **Enhanced Crew involvement**

Free Flyer
2009 – 2015
(and beyond)



Complementary Capabilities

- **Long Duration continuous sub-micro-gravity environment**
- **Eccentric orbits**
- **Radiation environment beyond the Van Allen belts**
- **Use of hazardous species, materials, and techniques**
- **On-demand launch and return**

1985 **2015**

OBPR's Organizing Questions

(http://spaceresearch.nasa.gov/general_info/strat_lite.html)

Humans will extend the exploration of space. To prepare for and hasten the journey, OBPR must answer these questions through its research:

How can we assure the survival of humans traveling far from earth?

How does life respond to gravity and space environments?

What new opportunities can our research bring to expand our understanding of the laws of nature and enrich lives on Earth?

What technology must we create to enable the next explorers to go beyond where we have been?

How can we educate and inspire the next generation to take the journey?

Organizing Question 1. How can we assure the survival of humans traveling far from Earth?

Research Targets	Today	2004-2008	2009-2016	OUTCOME
Mitigate and manage human adaptation risks	55 risks identified for outcome-driven research Promising countermeasures identified and studied Knowledge obtained using ground-based mechanistic studies	**Characterize and assess critical risks** **Advance understanding of mechanisms** Develop and test candidate countermeasures using ground-based analogs and space flight	Evaluate and validate system-targeted countermeasures to prevent or reduce risks Complete initial in-flight testing of optimized set of countermeasures (artificial gravity with other countermeasures)	**Ability of humans to retain function and remain healthy during and after long-duration missions beyond low-Earth orbit**
Reduce uncertainties and prevent exposure to space radiation environments	Uncertainties exist in estimating radiation risks Study of mechanistic effects in work Exposure mitigated using EVA scheduling and dose limits	Reduce uncertainty by one-half Expand mechanistic understanding using other models Develop and test new countermeasures	Assure at a 95-percent confidence interval crewmembers will not exceed radiation risk limits for longer-duration missions Test and evaluate biomedical and operational countermeasures	
Maintain behavioral health and optimal function of crews	Psychosocial functioning and behavioral health status studied for individuals Sleep protocols implemented Psychosocial function and performance studied for small groups in remote settings	Identify key psychosocial and psychological stressors Develop and test assessment methods, tools, and models Develop and test optimized countermeasures through ground and space research	Complete identification and increased understanding of psychosocial and behavioral health issues Validate assessment methods and tools Verify and validate countermeasure strategies	
Develop autonomous medical care capabilities	Stabilize and return medical care model developed Screening and select-in criteria in place for current mission scenarios	Develop standardized approach to track health status Determine clinical trends and define acceptable levels of risk Perform research to enhance medical capabilities, including screening, countermeasures, and treatment regimens	Determine acceptable levels of risk for longer-duration missions, and test and validate countermeasures Identify and assess crew screening and certification for longer-duration missions Demonstrate autonomous medical care capabilities	
Research Capabilities	**Ground labs including analogs, Shuttle, ISS**	**Ground labs including analogs, Shuttle, ISS**	**Ground labs including analogs and integrated testing, Shuttle, ISS, free flyers**	

Organizing Question 2. How does life respond to gravity and space environments?

Research Targets	Today	2004-2008	2009-2016
Determine how genomes and cells respond to gravity	Data on various cell types collected in short-term studies	**Develop physical and genetic models of cellular responses to space environments for a variety of organisms**	**Develop cell-based model assays to identify cellular systems affected by space; Integrate biological effects with cell communications**
Determine how gravity affects organisms at critical stages of development and maturation	Incomplete life cycle and ground-based data gathered from short-duration flights	**Use ground-based simulators, nanosatellites and ISS to determine gravity responses for a wide variety of organisms**	**Determine gravity thresholds and developmental responses in space using centrifuges on ISS**
Understand interactions among groups of simple and complex organisms	Ground-based virulence studies performed, lack systems supporting mixed organisms in space	**Model effects of space environments on pathogenic and cooperative interactions among species**	**Identify microorganisms that become pathogenic or otherwise alter function in space environments**
Determine how Earth-based life can best adapt to different space environments through multiple generations	Preliminary multi-generation flight research performed on plants	**Raise species from multiple kingdoms through several generations in flight; focus on reproductive success**	Raise mammals through multiple generations in flight; investigate developmental adaptations and critical issues
Research Capabilities	**Ground labs, Shuttle, ISS**	**Ground labs, Shuttle, ISS, nanosatellites**	**Ground labs including analogs and integrated testing, Shuttle, ISS, free flyers**

OUTCOME

Ability to predict responses of cells, molecules, organisms, and ecosystems to space environ-ments

Organizing Question 3. What new opportunities can our research bring to expand understanding of the laws of nature and enrich lives on Earth?

Research Targets	Today	2004-2008	2009-2016
Determine how space environments change physical and chemical processes	Research hampered by gravity-driven effects; gravity effects not understood in many technologies	Conduct ground and flight research to develop and validate models for fluid, thermal, combustion, and solidification processes	Test extended range models for heat transfer and microfluidic control, turbulent and high-pressure combustion validation; nanotechnology-based materials with enhanced and adaptive properties
Understand how structure and complexity arise in nature	Limited experimental data collected on self-assembly, self-organization, and structure development processes	Conduct ground and space research in solidification dynamics, colloidal photonics, carbon nanostructures	Research new technologies for advanced photonic materials Test solidification models using industrial systems Conduct flight investigations in turbulent combustion, granular material systems, and flows
Understand the fundamental laws governing time and matter	Data of unprecedented accuracy obtained in microgravity	Conduct research in dynamics of quantum liquids, atomic clock reference for space Develop technology for nanogravity satellite relativity experiments	Test Bose-Einstein condensates atom laser theories Use satellite experiments to test second-order models of general relativity
Identify the biophysical mechanisms that control the cellular and physiological behavior observed in the space environment	**Results obtained from Earth-based bioreactor and space-based tissue culture need validation; space-based improvements in protein crystal structures need validation**	**Conduct tissue-based research and engineering in space test models for fluid-stress and cellular response mechanisms** **Quantify key physiological signals** **Complete space-based flight research and establish validation of impact on structural biology**	**Test control strategies for cellular response to fluid stresses** **Integrate NASA technologies and research with biomedical needs**
Research Capabilities	**Ground labs, Shuttle, ISS, KC-135 aircraft**	**Ground labs, Shuttle, ISS, KC-135 aircraft**	**Ground labs, Shuttle, ISS, KC-135 aircraft, free flyers**

OUTCOME

Application of physical knowledge to new technologies and processes, particularly in areas of power, materials, manufacturing, fire safety

New insights into theories on fundamental physics, physical/chemical processes, and self-organization in structure

Organizing Question 4. What technology must we create to enable the next explorers to go beyond where we have been?

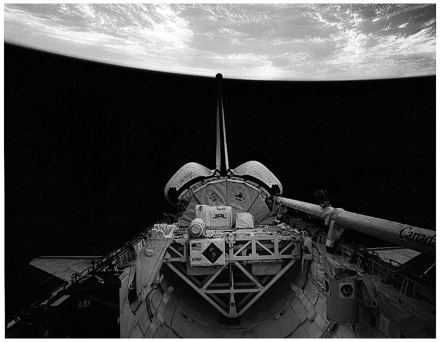
Research Targets	Today	2004-2008	2009-2016
Increase efficiency through life-support system closure	Current ISS baseline is a 90-day resupply Components with improved efficiency are the focus	Develop technologies that lower Equivalent System Mass (ESM) Perform integrated testing of lower ESM life-support technologies and subsystems in relevant environments	Perform on-orbit validation of critical components and certification of life-support technologies for missions beyond LEO Perform integrated testing of life-support systems with humans in the loop
Enable engineering systems and advanced materials for safe and efficient space travel	High-mass/cost, low-performance materials used Understanding of low- and partial-gravity issues incomplete	Develop and test low- and partial-gravity fluid and thermal engineering systems Develop and test design tools for advanced materials and in-space fabrication, and validate on ISS	ISS experiments to test prototype engineering systems Complete development of advanced materials for radiation-shielding solutions Validate prototype low- and partial-gravity resource-generation technologies
Enable self-supporting and autonomous human-systems for performance in habitable environments	Predictive methods and models limited for habitability analysis, information management, crew training, multi-agent team task analysis, integrated human systems engineering	Define and develop habitats that optimize human performance Develop tools and models for human-systems integration	Validate habitat designs for multiple missions Validate human-system design simulation Deliver validated design require-ments and integrated simulation tools for multiple missions
Develop advanced environmental monitoring and control systems	Technologies exist for partial monitoring of ISS environment Individual sensors developed	Develop sensing capabilities for 90% of existing air Spacecraft Maximum Allowable Concentrations (SMACs) Develop sensing capabilities and SMACs to monitor water Develop autonomous controls architecture design	Develop miniaturized, reali-time, efficient sensing capabilities for air and water Validate integrated systems
Research Capabilities	**Ground facilities, simulators, Shuttle, ISS, KC-135 aircraft**	**Ground facilities, Shuttle, ISS, KC-135 aircraft**	**Integrated ground test facilities, Shuttle, ISS, KC-135 aircraft, free flyers**

OUTCOME

New technologies that provide for more efficient, reliable, and autonomous systems for sustainable human presence beyond low-Earth orbit

Expanding OBPR's research capabilities

Space Shuttle
1985 - 2015



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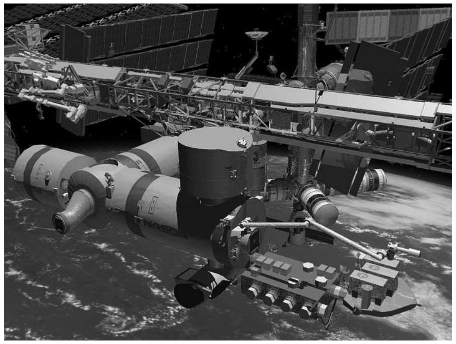

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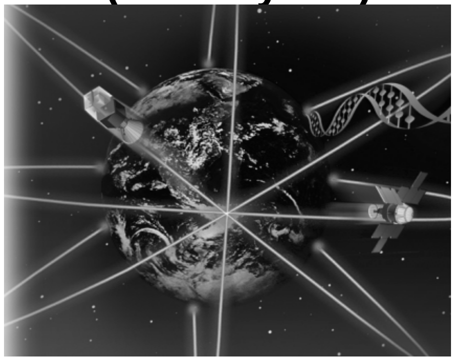
2009 – 2015
(and beyond)



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